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Contrasts in Certain Physical Factors in Fagus-Acer and Quercus-Carya Communities in Brown and Bartholomew Counties, Indiana

RAY C. FRIESNER *and* J. E. POTZGER

A Quantitative Study of the Phytoplankton of the White River Canal, Indianapolis, Indiana

CHARLENE COFFING

These papers are contributions No. 80, 81, respectively, from the botany laboratories of Butler University. Address all communications regarding them to Butler University Botanical Studies, Butler University, Indianapolis, Indiana, U. S. A.

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CONTRASTS IN CERTAIN PHYSICAL FACTORS IN FAGUS-ACER AND QUERCUS-CARYA COMMUNITIES IN BROWN AND BARTHOLOMEW COUNTIES, INDIANA

By Ray C. Friesner *and* J. E. Potzger

Oak-hickory forests occur in Indiana under three sets of ecological conditions. First, in the northern fifth of the state, roughly north and west of the Tippecanoe river (except for the northeast corner, i. e., Steuben and part of Lagrange counties), they are the most mesophytic type of forest that will be permanently maintained by the general climate of the area and, therefore, become the climax association. Second, in the southern four-fifths of the state the general climate is such as to support beech-maple as the most mesophytic forest-type capable of permanent maintenance and they there become the climax. However, within this area where beech-maple is climax, oak-hickory occurs on sites where edaphic and physiographic conditions combine to render the areas more xeric, and oak-hickory is the most mesophytic forest community capable of being maintained under the present environmental conditions. Under these conditions there will be an indefinitely prolonged period during which oak-hickory is the end of ecological succession. Since this end of succession will be due to edaphic and physiographic reasons and not by reason of the general climate, oak-hickory becomes subclimax on these sites.

The third set of conditions under which oak-hickory occurs in Indiana is on sites which in every way are capable of supporting beech-maple communities but where forest succession has not progressed to the final or climax stage. Such sites show oak-hickory predominating so far as crown-coverage and density of mature stems are concerned, but the reproduction as shown by density of younger stems is mostly beech and maple and the ultimate end of succession will be beech-maple unless general climate conditions are changed. Under such conditions oak-hickory is preclimax.

The transition from beech-maple climax of the southern four-fifths of the state to oak-hickory climax in the northern fifth is coincident with a change in average annual rainfall from 38 inches to 35 inches, the latter soon followed by a further drop to 33 inches.

With a view to analyzing some of the factors concerned in differentiating and determining the beech-maple climax and the oak-hickory subclimax, studies were carried on from the following standpoints: available soil moisture, evaporation demands, soil acidity relation, floristic composition, and character of herbaceous flora. Data obtained from the first three of the above standpoints are brought together under the present heading, while data from the last two standpoints will be presented in a subsequent paper.

AVAILABLE SOIL MOISTURE

Three of our areas were so situated and showed the necessary floristic composition to be used as direct contrasts between beech-maple and oak-hickory communities. These areas gave a total of five beech-maple communities to be contrasted with a similar number of oak-hickory communities. A brief explanation of these areas follows.

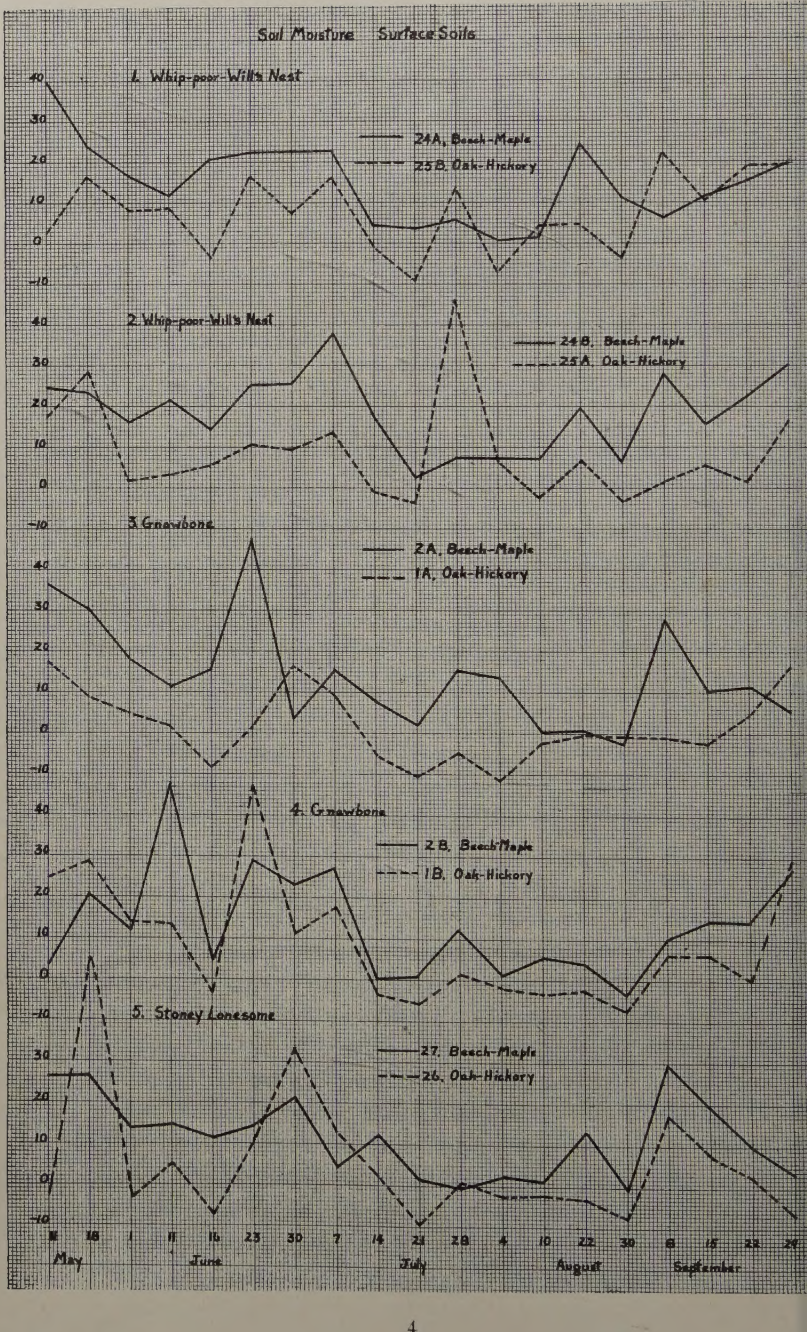
Whippoorwill's Nest. This area comprised a very narrow-topped east-west ridge in Brown county, locally known by the above name, with heavily wooded steep north-facing slope (Area 24 A, B) and somewhat less heavily wooded south-facing slope (Area 25 A, B). The north-facing slope comprised chiefly beech-maple with some Liriodendron and *Quercus borealis maxima,* while the south-facing slope contained primarily *Quercus velutina, Q. coccinea, Q. alba* and *Q. montana,* with some *Carya glabra.* Each slope was divided into upper and lower portions: 24 A and 25 B comprising lower portions of their respective slopes and 24 B and 25 A comprising upper portions.

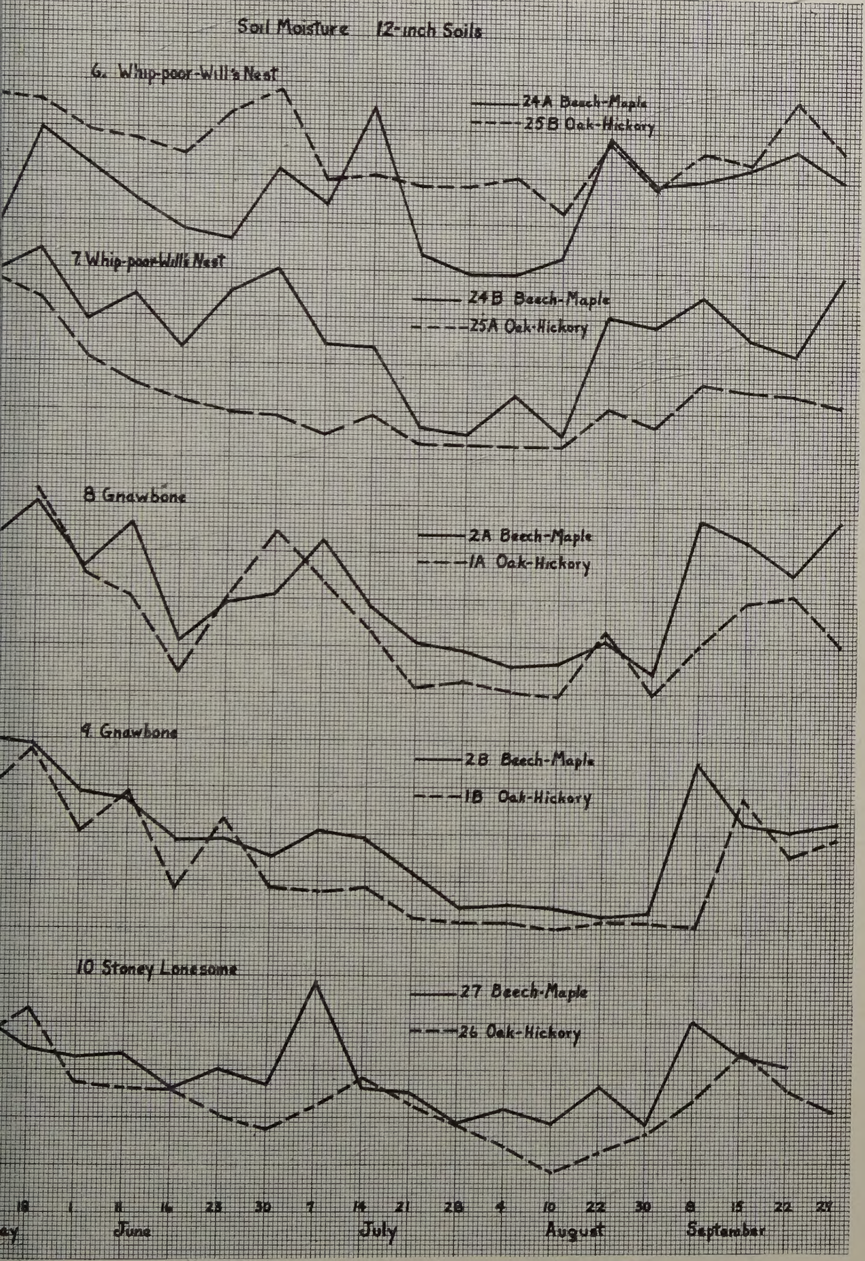
Gnawbone. This area comprised a north-facing slope (Area 1 A, B) and a south-facing slope (Area 2 A, B), on opposite sides of the same narrow valley. It is located about one mile northeast of Gnawbone in Brown county. The north-facing slope was chiefly beech-maple with Liriodendron and *Quercus borealis maxima,* while the south-facing slope comprised *Quercus alba, Q. velutina, Q. coccinea* and *Q. montana* with *Carya glabra* and *C. ovata.* These ridges were neither so high nor their slopes quite so steep as those at Whippoorwill's Nest, but the floristic composition is very similar. Lower portion of the slopes was 1 A and 2 A respectively, while upper portion was 1 B and 2 B.

Stoney Lonesome. This area comprises a north-facing slope (Area 27) and a south-facing slope (Area 26) on opposite sides of a narrow valley It is located at Stoney Lonesome about one-half mile east of the Brown Bartholomew county line. The slopes are on opposite sides of Indiana Road 46. On the north-facing slope is a mature stand of almost pure beech-maple, while on the south-facing slope is a very much less mature tand of *Quercus velutina, Q. montana* and *Q. alba.* The ridges are still ower and the slopes less steep than either of the other stations.

Soil samples were taken at surface, 6-inch and 12-inch depths from ach of these areas at weekly intervals from May 11, to September 29, 934. Percentage of moisture in terms of dry weight of soil was deternined for each sample and from these percentages was subtracted the ercentage of unavailable water, thus giving the percentage of available noisture. Curves show the percentage of available water, or, when this alls to zero, minus percentages are given, showing the difference between he wilting coefficient of the soil and the percentage of water present. The details of technique used were the same as used in our earlier studies lealing with soil moisture, (4). A comparison of the curves (beech-maple s. oak-hickory: Curve 1 for Areas 24 A vs. 25 B, lower part of slope; Curve 2 for Areas 24 B vs. 25 A, upper portion of slope; Curve 3 for reas 2 A vs. 1 A, lower portion of slope; Curve 4 for Areas 2 B vs. 1 B, pper portion of slope; Curve 5 for Areas 27 vs. 26) shows very definitely hat surface soils in beech-maple areas are, with few exceptions, higher in vailable moisture than similar soils in oak-hickory areas. A comparison f the same curves shows also that surface soils rarely show lack of availble water in these beech-maple areas but very frequently do in our oak-ickory areas. Beech-maple areas showed lack of available water in urface soils for only two weeks of the season, viz., July 28 at Stoney onesome and August 30 at both Gnawbone and Stoney Lonesome. Beech-maple areas at Whippoorwill's Nest showed absence of available vater at no time during the season. In striking contrast to this, oak-ickory areas show absence of available water for eleven different weeks, s follows: at Whippoorwill's Nest, June 16, July 14, 21, and August 4, 0, 30; at Gnawbone, June 16, July 14, 21, 28, August 4, 10, 22, 30, nd September 8, 15; at Stoney Lonesome, June 1, 16, July 21, and ugust 4, 10, 22, 30. The similarity in dates when there was lack of availble soil moisture in oak-hickory areas at the different stations is all the nore striking when we note that the Whippoorwill's Nest station is five niles from Gnawbone, which is in turn five miles from Stoney Lonesome.

When we turn to 12-inch soils, Curves 6-10, we find again that, with ew exceptions, beech-maple soils are higher in available moisture than ak-hickory soils. The only exception of any consequence is found when he lower parts of the ridge at Whippoorwill's Nest are compared. Here Curve 6) the beech-maple soil on the north side of the ridge was lower n available moisture (except for three different weeks) than the oak-ickory soil on the south side of the ridge.


Soil Moisture Surface Soils
1. Whip-poor-Wills Nest
24A, Beech-Maple
25B, Oak-Hickory
2. Whip-poor-Will's Nest
24B, Beech-Maple
25A, Oak-Hickory
3. Gnawbone
2A, Beech-Maple
1A, Oak-Hickory
4. Gnawbone
2B, Beech-Maple
1B, Oak-Hickory
5. Stoney Lonesome
27, Beech-Maple
26, Oak-Hickory
40
30
20
10
0
-10
11
18
1
11
16
23
30
7
14
21
28
4
10
22
30
8
15
22
29
May
June
July
August
September


Soil Moisture 12-inch Soils
6. Whip-poor-Will's Nest
24A Beech-Maple
25B Oak-Hickory
7 Whip-poor-Will's Nest
24B Beech-Maple
25A Oak-Hickory
8 Gnawbone
2A Beech-Maple
1A Oak-Hickory
9 Gnawbone
2B Beech-Maple
1B Oak-Hickory
10 Stoney Lonesome
27 Beech-Maple
26 Oak-Hickory
18
1
11
16
23
30
7
14
21
28
4
10
22
30
8
15
22
29
ay
June
July
August
September

Twelve-inch soils more often showed moisture content falling belo wilting coefficient than surface soils. With the exception of Curve 6, beech maple soils showed much smaller number of weeks without available moisture than oak-hickory soils. Beech-maple soils showed lack of availabl moisture as follows: Whippoorwill's Nest (Curve 7), 2 weeks; Gnawbon (Curve 8), 4 weeks; Gnawbone (Curve 9), 5 weeks; Stoney Lonesom (Curve 10), 3 weeks. In contrast, oak-hickory soils showed lack of available moisture varying from 6 to 12 weeks, as follows: Whippoorwill' Nest (Curve 7), 12 weeks; Gnawbone (Curve 8), 6 weeks; Gnawbon (Curve 9), 10 weeks; Stoney Lonesome (Curve 10), 7 weeks.

Beech-maple and oak-hickory relations are reversed when lower portions of the ridge at Whippoorwill's Nest are compared. Here (Curve 6 beech-maple soil showed lack of available moisture for 10 weeks, whil oak-hickory soil showed similar lack for only 3 weeks.

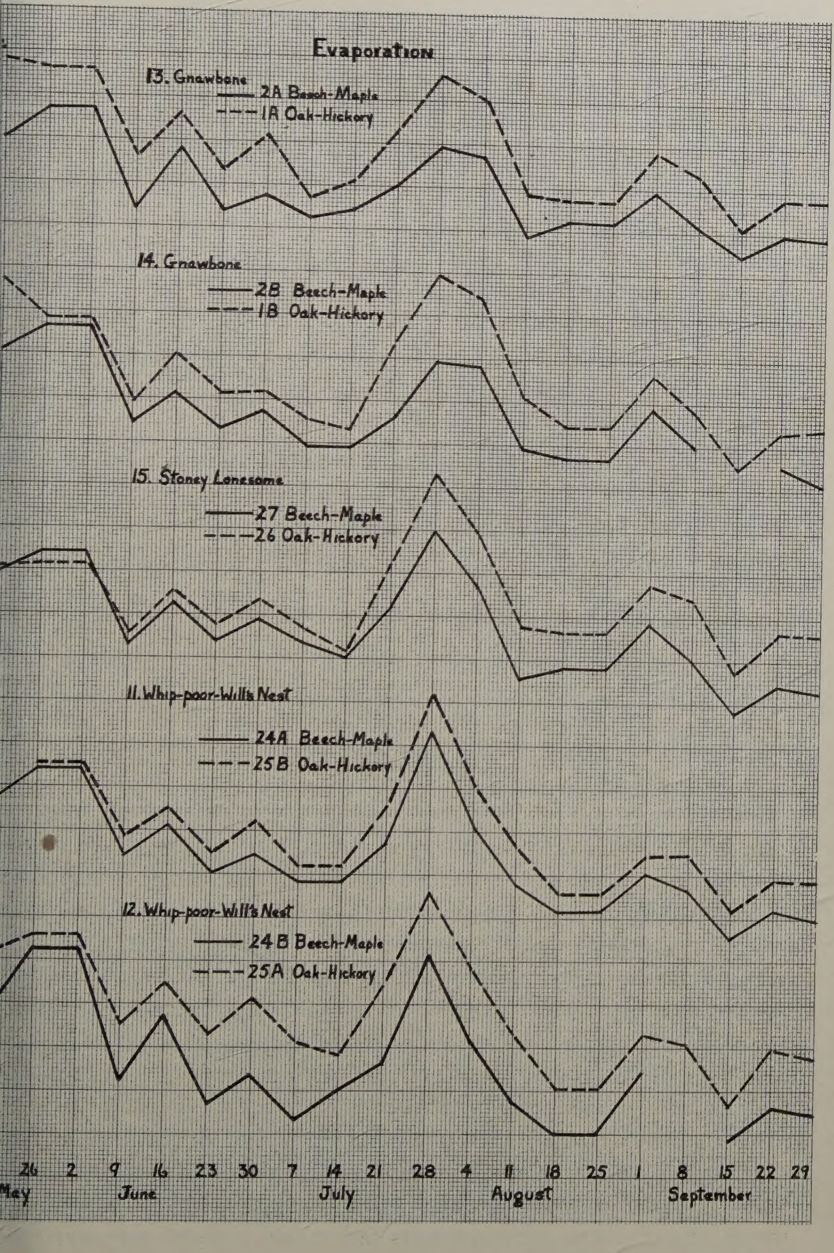
EVAPORATION

Livingston porous-cup white atmometers were set up in each statio and refilled weekly from May 12 to September 29. Evaporation los (standardized) for each station is shown in Curves 11-15. These curve show remarkable similarity in respect to periods of high and low evaporation, even though the stations varied up to ten miles apart. Comparison of curves for beech-maple and oak-hickory areas in the same localit and under comparable topographic conditions shows that for almost ever week and in every locality evaporation was greater in oak-hickory are than in beech-maple areas.

When water loss in beech-maple communities is compared with that i oak-hickory communities when the two are on opposite sides of the sam ridge or on opposite sides of the same valley, the more xerophytic character of oak-hickory sites is strikingly revealed. Average weekly water los in such comparable stations is shown below:

AVERAGE WEEKLY EVAPORATION

	Beech-Maple	Oak-Hicko
Whippoorwill's Nest—Lower part of ridge	71.92 cc.	87.25 cc
Whippoorwill's Nest—Upper part of ridge	77.03	112.42
Gnawbone—Lower part of ridge	55.19	85.45
Gnawbone—Upper part of ridge	80.15	104.84
Stoney Lonesome	80.45	100.73
Average of all stations	72.90	98.25


Evaporation
13. Gnawbone
2A Beech-Maple
1A Oak-Hickory
14. Gnawbone
2B Beech-Maple
1B Oak-Hickory
15. Stoney Lonesome
27 Beech-Maple
26 Oak-Hickory
11. Whip-poor-Wills Nest
24A Beech-Maple
25B Oak-Hickory
12. Whip-poor-Will's Nest
24B Beech-Maple
25A Oak-Hickory
26 2 9 16 23 30 7 14 21 28 4 11 18 25 1 8 15 22 29
May June July August September

If these data are compared with results obtained in other seasons and in other localities, it will be seen that the season of 1934 in Brown and Bartholomew counties was considerably more severe than any other season for which we have records available except the year 1930 in Brown county.

AVERAGE WEEKLY EVAPORATION

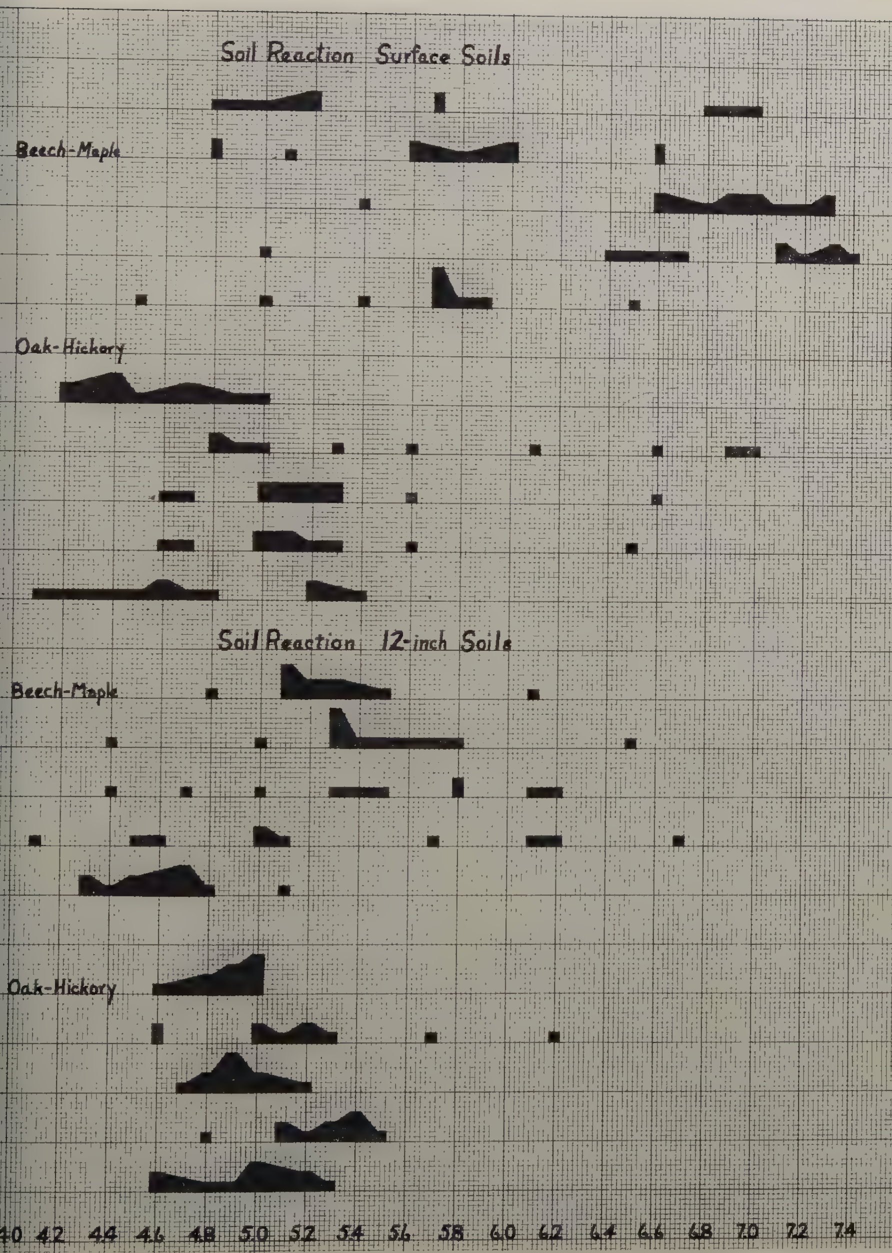
	Beech-Maple	Oak-Hickory
Chicago (5), 1910-1912	49.1 cc.	61.8 cc.
Washington-Idaho (7), 1914	58.8	
Sycamore Creek (Indiana) (1), 1928	46.2	56.8
Sycamore Creek (4), 1929	56.7	
Turkey Run (3), 1929	50.4	
Trevlac, Brown County (4), 1930	80.9	
Average stations in present study, 1934	72.9	98.25

If we use evaporation in the beech-maple association as a standard, we find that the oak-hickory associes in our studies shows up considerably more xeric than in any of the other studies that we have available for com-parison. This is shown in the following comparison:

Beech-Maple	100 cc. per week
Oak-Hickory—Chicago Area (5)	126 cc. per week
Oak-Hickory—Sycamore Creek (1)	123 cc. per week
Oak-Hickory—Average of present stations	135 cc. per week

SOIL REACTION

Soil reaction in each forest area studied was determined from ten samples at each of three depths, viz., surface, 3-inch and 12-inch soils Readings were made on the Youden apparatus. The range of reaction in surface soils for beech-maple does not show much difference from that o oak-hickory, except that the reaction spread is a little nearer alkalinity in beech-maple, extending from pH 4.5 to 7.53, and a little more acid in oak-hickory, extending from pH 4.1 to 7.24. Reference to the graphs where an attempt is made to indicate the number of samples giving a particular pH reading shows a better picture of the soil reaction results than mere pH range. Here it will readily be seen that the majority of the soil samples gave a decidedly more acid reaction for oak-hickory than was found in any of the beech-maple areas except one. It will also be seen that while the oak-hickory range exhibits as wide a spread as the beech maple, the majority of the samples fall within a much narrower rang


Soil Reaction Surface Soils
Beech-Maple
Oak-Hickory
Soil Reaction 12-inch Soils
Beech-Maple
Oak-Hickory
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4

which is much more acid than the majority of the readings for beech-maple soils.

When 12-inch soils are considered, we find that while beech-maple exhibits a considerably wider range in pH readings than oak-hickory soils the majority of beech-maple samples are massed in a part of the range with higher pH value than the majority of the oak-hickory samples There is a general tendency, therefore, for beech-maple soils to give a higher pH reading and oak-hickory soils to give a lower pH reading.

To what extent these two forest types are cause and to what extent they are effect of these pH differences it is difficult to say. Judging from the reaction ranges and comparing these with the position within the ranges where majority of readings occur for each type, it seems a fair conclusion that either forest type can tolerate a fairly wide range of soil reaction, but, once established, there may be a tendency for the decomposition products of the two forest types to be such that the net result is a higher acidity in oak-hickory soils than in beech-maple soils. This is to say, that it is likely that the difference in reaction of soil in these forest types is due more to the differences in vegetation than the reverse.

DISCUSSION

If we follow the concept of Clements (2) and consider the climax vegetation to be the most mesophytic type capable of being permanently supported by the climate of a region, it becomes quite clear that since beech maple is generally distributed over this south central portion of Indiana and not limited to isolated areas where edaphic and physiographic conditions give it sites more mesophytic than is general in terms of climate for the area, it is to be considered the climax forest type of the region Oak-hickory, occurring under the same general climatic conditions, but on sites where edaphic and physiographic conditions combine to make available soil moisture generally less and evaporation demands almost invariably greater, and hence on more xerophytic sites, must be considered as a subclimax associes.

It is likely that this oak-hickory associes will be of indefinite duration before the edaphic and physiographic changes necessary to transform the sites into those sufficiently mesophytic to permit succession to beech-maple. For this reason we use Clements' term "subclimax" here and reserve his term "preclimax" for those oak-hickory communities which are on sites edaphically and physiographically capable of supporting eech-maple but where ecological succession has not yet reached the limax or final stage.

As noted by Potzger (6), the most characteristic single feature of the illy part of south central Indiana is this dual nature of the forest climax 'herein beech-maple is the climax and oak-hickory forms a subclimax of ndefinite duration.

SUMMARY

1. Oak-hickory occurs in Indiana under three sets of ecological condi- ons, i. e., climax, subclimax and preclimax.

2. In areas where oak-hickory is subclimax or preclimax, beech-maple orms the climax.

3. Subclimax oak-hickory is the end of forest succession and will per- ist for periods of indefinite duration on those sites where edaphic and hysiographic factors render the conditions more xeric than are general or the larger region, but climax oak-hickory occurs in the northern fifth f the state, where average annual rainfall drops rather suddenly from 8 to 35 inches, followed by a second drop to 33 inches.

4. Preclimax oak-hickory occurs on sites where conditions are capable f supporting beech-maple but where ecological succession has not yet eached the final or climax beech-maple stage.

5. When subclimax oak-hickory is compared with climax beech-maple, vailable soil moisture is lower and evaporation demands higher for almost ll of the late spring and summer season in oak-hickory than in beech- aple communities.

6. Soil acidity shows no striking difference in beech-maple and oak- ickory sites, except that surface soils under oak-hickory are more acid an those under beech-maple.

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A QUANTITATIVE STUDY OF THE PHYTOPLANKTON OF THE WHITE RIVER CANAL, INDIANAPOLIS, INDIANA[1]

By Charlene Coffing

Numerous quantitative investigations of lake and river plankton are ecorded for this country, but there seems to have been little work done n quantitative studies of canal phytoplankton. The present quantitative nvestigation of one year on the phytoplankton of the White river canal n Indianapolis, Indiana, follows a previous year of study of the taxonomy nd periodicity of the plankton flora of that canal (3). There are apparntly no published records of quantitative studies of plankton made in the icinity of Indianapolis.

REVIEW OF LITERATURE

In 1913, Allen (1) reported results of a quantitative study of the plankon of the San Joaquin river and its tributaries in and near Stockton, alifornia. One of the tributaries investigated was Smith canal, located bout 400 yards from the San Joaquin river. Smith canal was a straight hannel about 60 feet wide and two miles long, with a minimum depth of ne meter. This work constitutes the only reference to quantitative studies f canal plankton that the writer has found in American literature. Allen's nvestigations show that the phytoplankton of the canal was dominated y diatoms. He concluded that temperature is the principal factor determining plankton periodicity. Similar conclusions have been reached by her workers in regard to river and lake plankton.

The methods of making quantitative studies of canal plankton are very milar to the technique used in the investigation of river and lake ankton.

One of the outstanding studies of river plankton was made by Kofoid 0) in a quantitative investigation of the plankton of the Illinois river. e concluded that the plankton of the river channel was subject to great asonal and annual variations, minimum occurring during January and ebruary, and maximum occurring during April and June. The average onthly production declined gradually during the remainder of the year to the winter minimum in January and February. He found that the diatoms were more abundant than any other synthetic group of plankton organisms and exceeded the Chlorophyceæ seven to one.

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[1] This paper is a portion of a thesis in partial fulfillment of the requirements for the degree of ster of Arts in Butler University.

In the Illinois river only two main types or species groups of plankton were found, the summer and the winter types. The vernal and autumnal species were only transitions between summer and winter when organisms from both were present. The winter plankton of the river was composed of a small number of species peculiar to that season, and several perennial forms, while the summer plankton consisted of a large number of summer organisms with the perennial types.

Allen's (1) analysis of the plankton of the Smith canal confirmed, in part, some of the conclusions obtained by Kofoid for the Illinois river plankton. As in Kofoid's investigation, the phytoplankton was dominated by diatoms, while the Chlorophyceæ were frequent but not abundant. Some of Allen's conclusions are as follows: temperature, within certain limits, determines the seasonal distribution of plankton; water currents above a very moderate rate of flow are inimical to the development of plankton; collections taken at intervals of one week or more do not give sufficient data for accurate determination of plankton distribution through the year, but daily collections would probably do so.

In an ecological study of the Hocking river in Ohio, Roach (18) found that phytoplankton varied in abundance in direct ratio with the temperature. Diatoms were the dominant plankton flora, with the Chlorophyceæ second in abundance. Eddy (5), in an ecological study of fresh-water plankton communities, including some rivers, lakes and ponds in Illinois, found that the abundance of fresh-water plankton at different seasons in the same body of water varies directly with the temperature. Kraatz (12), in a quantitative net-plankton survey of East and West reservoirs, near Akron, Ohio, found that diatoms reach a distinct spring maximum in May. The autumn maximum, beginning in late summer, was not nearly so great as the spring maximum. In a limnological study of Lake Erie Gottschall and Jennings (6) found diatoms to be the most abundant group of planktonts, this group exhibiting the characteristic spring and fall peaks of abundance.

An indication of the difference in periodicity between the plankton of rivers and lakes is seen when Kofoid's results on the Illinois river are compared with the Wests' work on some British lakes. The Wests (20) found that the greatest amount of phytoplankton, both quantitatively and qualitatively, occurred in late summer and autumn, during the autumna cline in temperature. They are convinced that the most important fac- in both the quantitative and qualitative distribution of plankton is the ount of dissolved salts present in the water.

The predominant assumption in literature is that periodic changes in plankton content of a body of water are due chiefly to temperature riations. It has been assumed that diatoms require lower temperatures development, since they are usually most abundant during the cooler sons. Pearsall (14) asserted that it is improbable that temperature ne is of any great importance in determining the periodicity of diatoms. concluded that the real underlying causes are factors which normally erate during cold weather, namely, the fact that nitrates are washed m the soil most rapidly in cooler seasons when rainfall is in excess of aporation, the fact that heavy rainfall causes a washing of dissolved ca from the soil, and the fact that rainfall increases the oxygen content the water.

In a later study, Pearsall (16) emphasized the importance of dissolved stances in the water as a determining factor in the abundance and sonal distribution of plankton. Diatoms occur in winter and spring en the waters are richest in nitrates, phosphates and silica, while the en algæ occur in summer when nitrates and phosphates are low.

Whipple (21) emphasized the importance of the vertical circulation ich occurs in a body of water in spring and autumn. This phenomenon ngs to the surface any accumulation of organic matter, which is then dized. Some of the products of oxidation are favorable to the growth diatoms. During the period of vertical circulation, the diatoms, or ir spores, which have been lying dormant at the bottom, are carried the surface by the vertical currents. The extent of the development diatoms depends upon the amount of food material present and the perature of the water. The periods of minimum development are ing periods of stagnation.

FEATURES OF THE WHITE RIVER CANAL

Canals have certain features which distinguish them from rivers, nely a relatively slower rate of flow, a more uniform depth and a er amount of aeration or oxidation. A possible difference in tem- ature may exist, due to the fact that the slower the rate of movement water, the more likely it is to be affected by the temperature of the air. White river is the source of the water of the White river canal. The headwaters of White river and its tributaries rise in glacial drift which i high in lime and magnesia. About 40 per cent of the rainfall seeps through several feet of glacial drift. The ground water leaches out the lime and magnesia, making the water high in temporary and permanent hardness About 25,000,000 gallons per day of ground water flow into White rive in the 60 miles or more of its length above Indianapolis (7).

The canal is about 8.8 miles long, averaging 60 feet wide and 6 fee deep. Its rate of flow is rather slow, and is controlled by headgates in sluiceways at Broad Ripple (8). It is characterized by having water o rather low turbidity, a lack of benthon and marginal vegetation, and the presence of fish and mussels. It passes through the outskirts of the city and is relatively unpolluted.

PURPOSE OF THE INVESTIGATION

A qualitative study of the phytoplankton of the White river canal made by the writer in 1933-34 (3) was introductory to the presen quantitative investigation made in 1934-35. The present investigation was undertaken for the primary purpose of securing more definite infor mation regarding the plankton flora of the canal as expressed in numbe of organisms per cubic centimeter, and of classifying the different genera into ecological groups according to their seasonal distribution and time of maximum. As a secondary purpose, an attempt was made to deter mine the correlation between temperature of water and the abundance and occurrence of the classes of phytoplankton and of the total phyto plankton.

LIMITATIONS OF THE INVESTIGATION

This survey includes only the phytoplankton, no attempt being made to include the unpigmented planktonts. The organisms were listed by genus only, since the species of many small forms could not be deter mined by using only a 16 mm. objective. Because of the low magnifica tion used, a number of forms could not be identified even to genus, and consequently had to be listed as unknown.

Results are given in terms of number of organisms per cubic centi meter of canal water. In this investigation the term "number of organ isms" refers to the number of cells when dealing with isolated unicells and to the colony or filament when counting colonial and filamentou forms. Genera such as Pediastrum and Tribonema, regardless of th ımber of cells each possessed, were always counted as a unit. The ethods of "standard units" in which the size of organisms is deterined, and of "cubic standard units" in which the cubic centimeters of ankton per cubic meter of water is expressed (Whipple, 21) were not ed. No attempt was made to determine the weight of plankton or of ganic matter of the plankton (Birge and Juday, 2). In connection th this investigation, several major environmental factors were not udied, temperature of water being the only agent with sufficiently curate data for presentation. Further limitations of this study include e time limit, the investigation being carried on over a period of only ty weeks; the fact that samples were collected only once a week; the ct that samples were collected at only one depth; and the fact that mpling was done at only one location.

METHODS AND APPARATUS

COLLECTION

The procedure followed in the investigation consisted in, (1) colction of samples; (2) concentration by filtration and preservation of e residuum; (3) the examination of the concentrate and the enumeraon of the phytoplankton; (4) the calculation of the number of organns per cubic centimeter.

A collection was made every Monday during the middle of the day om June 4, 1934, to May 13, 1935, covering a period of fifty weeks. mples were obtained from near the canal bridge on the Butler Unirsity campus. This sampling point is 2.6 miles from the place where e canal begins. The sampling apparatus consisted of two one-half llon Mason fruit jars equipped with a rope. Collections were made the center of the canal at a depth not exceeding six inches below the rface of the water, the jars being lowered by a rope from the edge of e bridge. A sufficient amount of water was secured to concentrate plicate samples of 1000 cc. A thermometer was placed in one of the rs as soon as the water was drawn, and the temperature in degrees ntigrade was read through the jar. The sample was taken immeately to the laboratory and concentrated. The method of concentraon used was the Sedgwick-Rafter method in which a measured quantity the sample is filtered through sand.

Examination and Enumeration

The equipment used in the microscopic examination of the concentrated samples of plankton consisted of a compound binocular microscope equipped with a mechanical stage and 20X oculars, a Whipple ocular micrometer and a Sedgwick-Rafter counting cell. It was almost impossible to recognize with certainty many of the genera when the microscope was calibrated in the usual manner so that the area on the stage covered by the Whipple ocular micrometer was one square millimeter. Consequently, a calibration was worked out whereby a portion of the micrometer would cover an area on the stage exactly .25 square millimeter. Since the counting cell was one millimeter deep, the volume within the outlines of the 49 squares was .25 cubic millimeter.

In the enumeration of the number and variety of organisms present, four fields in each of the duplicate samples were counted, making eight counts for each week's collection. Since the volume per field was .25 cubic millimeter, one cubic millimeter per sample or two cubic millimeters per weekly collection were examined. In the enumeration, cells of organisms touching the upper and left-hand boundaries of the field were not counted, while cells touching or overlying the lower and right-hand limits of the field were counted, as is recommended for blood corpuscle work (Kilduffe, 9). From the counts obtained, the number of organisms per cubic centimeter of canal water was calculated.

The writer realizes that the method of counting only eight fields of .25 cubic millimeter each per collection does not give such representative results as would the customary method in which 10-20 fields of one cubic millimeter each are counted, yet the writer felt justified in using a method whereby greater magnification could be obtained so that recognition of genera would be easier and more accurate.

RESULTS

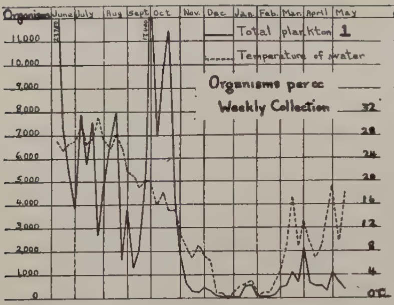
In the 50 collections taken from the White river canal, 39 genera of algæ, representing 7 classes, were recorded. The classes recorded individually were the Myxophyceæ, Chlorophyceæ and Bacillarieæ, since they are usually the classes of algæ found most abundantly. The other four classes were the Chrysophyceæ, Desmidiaceæ, Euglenophyceæ and Heterokontæ. There were some members of the Bacillarieæ and Chlorophyceæ which could not be identified to genus and were listed as

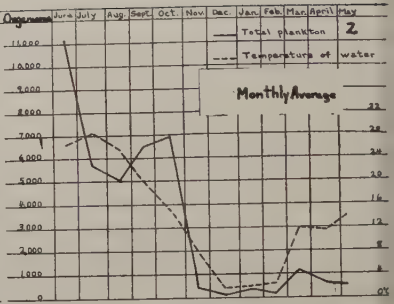
nknown" under their respective groups. In addition, there were a few
er algæ whose identity could not be determined and which were
ced in the Miscellaneous Group as "unknown." The genera identified
given in an ecological classification following these results.

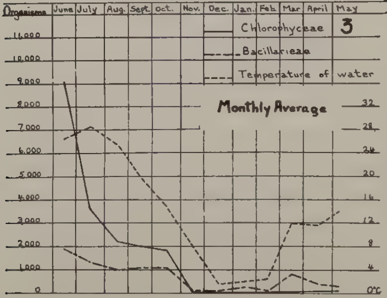
The average number of organisms per cc. per week was 3,338, with a
ge from a maximum of 27,750 per week on June 4, 1934, to a mini-
m of 45 per week on February 4, 1935. The average number of
era of algæ per week was eight, with a range from 18 on June 4,
34, to two on December 31, 1934, January 28, and February 11, 1935.

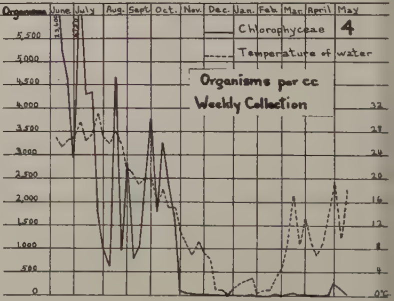
The total amount of plankton occurring in the weekly collections
m June 4, 1934, to May 13, 1935, showed definite seasonal varia-
ns and also conspicuous weekly variations, especially from June to
tober. Two periods of maximum occurrence were evident, the higher
k occurring on June 4 and the lower peak on September 24. When
sidering the monthly averages, June and October were the months
greatest amplitude (Figure 2). The maximum in June was due to an
ndance of Chlorophyceæ (Figure 4) and diatoms (Figure 3), but
October maximum was due mainly to the appearance of Tribonema
large numbers. In October the Chlorophyceæ were declining (Figure
and diatoms showed only a slight increase (Figure 3). Both maxima
wed no definite correlation with temperature. In June, the average
perature was lower than in July (Figure 2), yet the plankton was
ch more abundant in June, especially during the first part of the
nth, than in July. In October, the peak in total plankton was pre-
ed and accompanied by a fairly rapid and steady decline in tem-
ature. Except for these two maxima of plankton, the plankton pro-
tion and temperature were, in general, fairly well correlated (Figure
The best correlation came between November and April, when
perature seemed to be the controlling factor, but from June to
ober, 1934, and beginning in May, 1935, there were apparently other
etermined factors which played a part in influencing plankton pro-
tion.

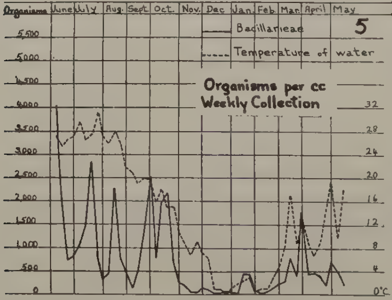
nly the Chlorophyceæ and Bacillarieæ were considered in detail as
ime of occurrence and relative abundance, since they comprise most
he plankton of the canal. The very prominent weekly fluctuations
mounts of Chlorophyceæ during summer and early autumn are shown
Figure 4. Those of the Bacillarieæ during summer, early autumn
spring are shown in Figure 5. The results of Kofoid (11), West
) and Whipple (21) show maxima varying from spring to autumn.

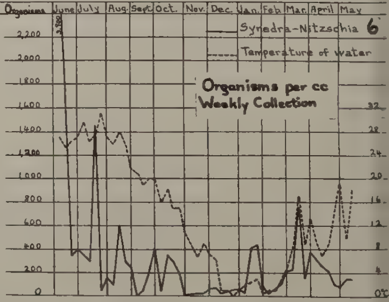

Organisms
June July Aug Sept Oct Nov. Dec. Jan. Feb. Mar. April May
Total plankton 1
Temperature of water
Organisms per cc
Weekly Collection
11,000 10,000 9,000 8,000 7,000 6,000 5,000 4,000 3,000 2,000 1,000 0
32 28 24 20 16 12 8 4 0°C

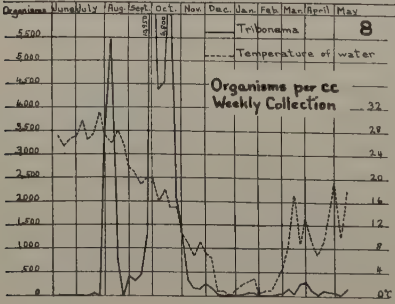

Organisms
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May
Total plankton 2
Temperature of water
Monthly Average
11,000 10,000 9,000 8,000 7,000 6,000 5,000 4,000 3,000 2,000 1,000 0
32 28 24 20 16 12 8 4 0°C

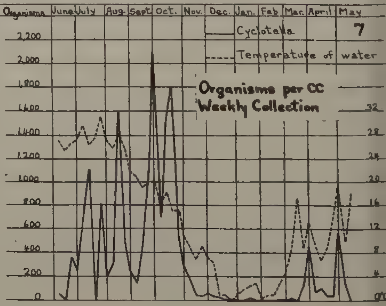

Organisms
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May
Chlorophyceae 3
Bacillarieae
Temperature of water
Monthly Average
11,000 10,000 9,000 8,000 7,000 6,000 5,000 4,000 3,000 2,000 1,000 0
32 28 24 20 16 12 8 4 0°C


Organisms
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May
Chlorophyceae 4
Temperature of water
Organisms per cc
Weekly Collection
5,500 5,000 4,500 4,000 3,500 3,000 2,500 2,000 1,500 1,000 500 0
32 28 24 20 16 12 8 4 0°C


Organisms
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May
Bacillarieae 5
Temperature of water
Organisms per cc
Weekly Collection
5,500 5,000 4,500 4,000 3,500 3,000 2,500 2,000 1,500 1,000 500 0
32 28 24 20 16 12 8 4 0°C


Organisms
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May
Synedra-Nitzschia 6
Temperature of water
Organisms per cc
Weekly Collection
2,200 2,000 1,800 1,600 1,400 1,200 1,000 800 600 400 200 0
32 28 24 20 16 12 8 4 0°C


Organisms
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May
Tribonema 8
Temperature of water
Organisms per cc
Weekly Collection
5,500 5,000 4,500 4,000 3,500 3,000 2,500 2,000 1,500 1,000 500 0
32 28 24 20 16 12 8 4 0°C


Organisms
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May
Cyclotella 7
Temperature of water
Organisms per cc
Weekly Collection
2,200 2,000 1,800 1,600 1,400 1,200 1,000 800 600 400 200 0
32 28 24 20 16 12 8 4 0°C

general, the curve for Chlorophyceæ parallels the temperature curve 'igure 3).

Scenedesmus was the most conspicuous genus of the Chlorophyceæ. times during the early summer months it comprised from one-third one-fourth the total phytoplankton, and outnumbered the other embers of the class several times. Kofoid (11) likewise found that enedesmus was the leading green alga numerically.

Diatom frequency is shown in Figure 3. It will be noted that the curve highest in June and lowest from November to February, with a spring aximum in March. In general, the diatom curve paralleled the temrature curve, which is contrary to the results of other workers (Whipe, pp. 228, 232). In previous work, the writer (3) found a diatom aximum in May, with a fairly uniform and abundant distribution rough the rest of the year. Two of the most important genera were nedra and Nitzschia. Whipple lists Synedra as a truly planktic genus iich exhibits spring and autumn maxima. In this investigation, nedra-Nitzschia were most abundant in the first collection on June 4, 34, and reached another peak in July. In general, they were most undant in the summer, declining to a winter minimum in November d December, exhibiting a rather feeble increase in January and an rly spring maximum in March, after which they declined (Figure 6). st how much of the deviation of this curve from the usual spring and l maxima of Synedra alone was due to the presence of Nitzschia uld not be determined.

Another genus probably as abundant as Synedra-Nitzschia was Cyclola, which was very abundant during the summer months, but increased a definite autumn maximum in October. It practically disappeared ring the winter, but reached a spring maximum of less amplitude in arch and April (Figure 7). The curve for Cyclotella is only partially agreement with Whipple's statement that it is one of the truly planktic itoms exhibiting spring and fall maxima, for although there is a defie increase in the spring, it is much more abundant during the summer onths than in the spring.

A striking ratio between the Chlorophyceæ and Bacillarieæ of the hal was discovered. The total Chlorophyceæ for the year outnumred the diatoms 2.5 to 1. In direct contrast are Kofoid's results (11), which the green algæ were outnumbered 6 to 1 by diatoms. Even eater difference was reported by Allen (1): the Chlorophyceæ being tnumbered by the diatoms 14 to 1. In Lake Erie and Presque Isle bay (6), diatoms were also the most abundant group. A few possibl explanations for these striking divergences are given. (1) Green phytoplankton (Chlorophyceæ) are more abundant at a higher level tha are diatoms (19). Since the samples from the canal were taken withi six inches of the surface, they would contain larger quantities of Chlorophyceæ in proportion to the amount of diatoms than the results o workers who have sampled at greater depths show. (2) Welch (19 refers to the work of Cilleuis (1928), in which the plankton of river and large streams possessing slow currents is characterized, in part, b having a lower diatom content than the plankton of rivers with a rapi current. The canal has a fairly slow current and therefore would ten to have fewer diatoms in proportion to the number of Chlorophyceæ (3) Streams with high turbidity, which indicates the presence of sil with silicon, have more diatoms than a less turbid body of water (15 19). Since the water of the canal exhibits relatively low turbidity, i would tend to have fewer diatoms than a more turbid stream. (4) According to Whipple (21), filtration through sand will retain the nannoplankto better than straining through bolting cloth. In case the smaller plankto were composed of more green algæ than diatoms, the use of sand woul obviously increase the amount of Chlorophyceæ.

Myxophyceæ were found in only two samples, June 25, 1934, an January 21, 1935. In studies of lake plankton, the Wests (20), Whippl (21) and Gottschall and Jennings (6) reported maxima of blue-gree algæ in autumn, usually after a period of hot weather. Kraatz (12) however, found a maximum in June, soon after the beginning of ho weather. In 1933, the writer (3) found that the blue-greens appeare the last of June, were fairly abundant during August and the first par of September, and disappeared by October. The maximum did not sho the relation to temperature that the above workers reported. It is possible that temperature of water is a minor factor influencing the occurrence and abundance of the Myxophyceæ. A factor which some workers emphasize is the amount of organic matter in the water. The West (20) reported the blue-greens to be largely absent from lakes with ver pure water, while White (22) stated that their abundance was probabl dependent upon the amount of nitrogenous matter in the water. If th amount of organic matter in the water is the more important factor, th fact that the writer found so few blue-greens indicates that the canal i relatively free from organic matter, or that the slow current of the cana allows much of the organic matter to sink to the bottom.

Tribonema was found in 41 of the 50 collections, at times in large umbers. Two periods of maximum occurrence were evident. The first ak occurred on July 30 and August 6 (Figure 8). The filaments ranged om fragments of two or three cells to many cells. The number declined a low level until September 24, when the maximum for the year of most 11,000 filaments and fragments of filaments per cc. were recorded. he number remained fairly high during October and decreased to a low vel during the winter and spring.

From the observations made by the writer and by other workers, ribonema seems to be primarily an autumn form. White (22) found ribonema to be the dominant alga in November and December, while elf (4) reported a definite maximum in February and March, with a sser maximum in October and November. The writer in 1933 found ribonema most abundant from August 21 to September 25, with the mperature of the water ranging from 21.5° to 24.5° C. In the present udy, Tribonema appeared in greatest numbers when the temperature nged from 15° to 22° C.

ECOLOGICAL CLASSIFICATION

In making an ecological classification of each genus found in the canal ring the two-year investigation, two factors were considered: the dis- bution of the organism through the year, and the numerical variation the organisms during the portion of the year that it occurred, with ecial emphasis on the time of greatest amplitude. The classification most of the genera was based upon results obtained during 1933-35 d upon data secured from an unpublished study of the plankton of hite river in and near Indianapolis from August, 1930, to September, 31 (13).

The 70 genera found during 1933-35 were grouped into four ecological sses with fairly definite periods of occurrence and times of maximum. fifth group was made, consisting of forms which were quite variable time of occurrence and time of maximum in the studies made, and of rms which appeared rarely. Some of the genera were not found in the llections of both years, and some were not reported in the year's vestigation of White river plankton (13). Consequently the classifica- n of some of the genera was based on only one year's observation. ch genera were listed as probably belonging in the various groups in

which they were placed. The five ecological groups and the genera con
prising them are given below:

Group I. June-October group, with maximum in June or July:

Actinastrum
Ankistrodesmus
Cœlastrum
Crucigenia
Dictyosphærium
Golenkinia
Kirchneriella
Lagerheimia
Micractinium
Pediastrum
Trachelomonas
Treubaria

Additional genera probably belonging in this group are:

Eunotia
Hemidinium
Phacotus
Schroederia
Staurastrum
Westella

Closterium, Lepocinclis and Phacus have been placed in Group
although their distribution approximates that of Group I.

Group II. July-November to all-seasons (continuous) group, wit
maximum June-October:

Cyclotella
Scenedesmus
Synedra-Nitzschia
Tribonema

Group III. October-May group, with maximum in March or April:

Diatoma
Gomphonema
Navicula

Group IV. March-May group, with maximum in March or April:

Asterionella
Cymatopleura
Cymbella
Gyrosigma

An additional genus probably belonging in this group is:

Meridion

Group V. Variable in time of occurrence and time of maximur
Includes rare forms. Abbreviation following each genus indicates mon
of maximum occurrence:

Closterium, July, Aug.
Dinobryon, Aug.
Euglena, March, July
Lepocinclis, July
Lyngbya, Aug.
Oocystis, Aug.
Oscillatoria, Aug.
Pandorina, Sept.
Phacus, July, Aug.
Selenastrum, July
Stauroneis, April
Tetrastrum, Aug., Sept.

Additional genera probably belonging to this group are:

Achnanthes, Dec.
Anabæna, Aug.
Botrydiopsis, Feb.
Carteria, July, Aug.
Cladophora, Feb.
Cœlosphærium, Oct.
Cosmarium, July
Cryptomonas, Oct.
Elaktothrix, July
Eudorina, Aug., Sept.
Fragilaria, March
Frustulia, April
Glœocystis, Aug.
Gonium, Sept.
Ceratium, Aug.
Chlamydomonas, July, Oct.
Chlorella, Aug., Sept.
Chroococcus, Sept.
Hantzschia, May, June, Nov.
Melosira
Nephrocytium, Sept.
Œdogonium, May
Ophiocytium, Sept.
Pinnularia, March
Quadrigula, Sept.
Sphærocustis, May
Surirella, Jan., Feb.
Tetradesmus, Oct.

It seems that the classification of *Cymatopleura solea* into Group IV ould be somewhat tentative. Although it may appear to be primarily pring form as found by Allen (1) at Station II, and by the writer, yet foid's results on the Illinois river and Allen's results on Stations I and , indicate that it might be considered as a variable form and hence ced in Group V.

The results of Kofoid, Whipple and Palmer differ considerably con- ning the occurrence of Diatoma. The writer's results are more similar Whipple's than to Kofoid's and Palmer's. Since the appearance of atoma was very similar during the two years' study, the writer felt tified in placing it in Group III.

The seasonal distribution of Actinastrum in the Illinois river (11) and the San Joaquin river (1) indicates that the genus unquestionably ongs in Group I, but when the time of maximum occurrence is con- ered, the writer's classification does not apply to the Actinastrum of er localities. Difference in temperature in different localities during same month may cause the variation in time of maximum, for the ter found the optimum temperature for Actinastrum to be practically same as Kofoid (11) reported. Another reason for the variation may in the difference in species. Allen and Kofoid reported *A. hantzschii,* ile the species in the canal was *A. gracillimum.*

Cœlastrum, another member of Group I, showed a much earlier maxi- m in the canal than it did in the Illinois river and San Joaquin river, ough the period over which it was present is much the same. Again, difference in temperature in different regions during the same month ma account for the difference in time of maximum occurrence. In agreemen with Kofoid (11), its maximum development was during the period o highest temperature.

The information secured on Pediastrum indicates that its classificatio into Group I would not hold true in other localities. However, the simi larity in seasonal distribution of the organism during 1930-31 (13) an 1933-35, places it in Group I in this region. Kofoid (11) found Pediastrum every month, and the optimum temperature was 15°-20° C., whil in the canal it occurred less than half the year and seemed to prefer temperatures of 20°-26° C.

The seasonal distribution of Scenedesmus in the canal coincides fairl well with information secured by other workers, and consequently it wa placed in Group II. Although it was a perennial planktont, it was predominant only during the warmer part of the year, at temperatures ranging from 15°-30° C.

Euglena is an exception in Group V in being rather common. However, its range and time of maximum were so different during the tw years that it could not be placed in any of the other groups. In 1933 i was present and fairly abundant from July to the latter part of September, but in 1934-35 it appeared only four times during the summer an eight times during early spring. Whipple (21) reported Euglena to b most abundant from June to September. Palmer (13), in samples take from White river below a sewage disposal plant, found Euglena more o less abundant throughout the year. White (22) emphasized the presenc of nitrates as a factor influencing the abundance of Euglena. A simila view was stated by Purdy (17), who named Euglena and its relatives a positive indicators of contamination. From results obtained on Euglen in the investigation of the plankton of the canal, the writer cannot lis temperature of water as a determining factor.

SUMMARY

1. A quantative study of the phytoplankton of the White rive canal from June 4, 1934, to May 13, 1935, was made by filtering weekl samples through sand and observing measured units of the concentrat at a magnification of 200.

2. The study revealed a marked periodicity of the total plankton an of the classes and genera of algæ.

3. The total plankton showed considerable weekly variation, but when
asonal distribution is considered, it exhibited a summer and early
tumn maximum which extended from June through October, and a
nter minimum which lasted from November through February. Dur-
g the winter minimum the plankton curve was uniformly low, but the
aximum showed two peaks of abundance, the larger occurring in June
d the smaller in October. The October peak was caused by a sudden
d large increase in the amount of Tribonema. The total plankton
owed a small increase in March, due mostly to diatoms, however.

4. The maximum average monthly production of total plankton,
lorophyceæ and Bacillarieæ occurred in June.

5. The Chlorophyceæ showed considerable weekly fluctuation. When
onthly averages were considered, the green algæ were abundant from
ne through October and dropped suddenly in November to a winter
nimum which lasted until May.

6. The green algæ followed the temperature curve fairly closely except
ring March, April and May, when they failed to increase with the
mperature.

7. Of the Chlorophyceæ, Scenedesmus was by far the most abundant,
times during early summer comprising from one-third to one-fourth
e total phytoplankton.

8. The Bacillarieæ showed a summer and early autumn maximum, a
nter minimum, and an increase in March when the temperature
creased.

9. The diatom curve fluctuated more from week to week than the
lorophyceæ curve, but the diatoms showed almost as close correlation
the temperature curve as did the green algæ.

10. Of the Bacillarieæ, Synedra-Nitzschia was conspicuously abundant
ring early summer, and less abundant in early spring, while Cyclotella
s dominant in late summer and early autumn.

11. The Chlorophyceæ were the dominant class of algæ in the canal,
tnumbering the diatoms 2.5 to 1.

12. The Myxophyceæ of the canal were almost entirely absent, occur-
g in only two of the 50 collections.

13. Tribonema, although present and at times abundant during late
mmer, reached a maximum in October during the autumnal decline
temperature. It exhibited tolerance of low temperatures, being present,
hough in small numbers, during most of the winter.

14. In general, temperature seemed to be a primary factor influencing

plankton production. At times, however, there were apparently oth undetermined factors which played an important part in phytoplankt periodicity.

15. From records of three years, the algæ of the canal were plac in five ecological groups, which are as follows:

Group I. June-October group, with maximum in June or July.

Group II. June-November to all-seasons (continuous) group, wi maximum June-October.

Group III. October-May group, with maximum in March or April.

Group IV. March-May group, with maximum in March or April.

Group V. Variable in time of occurrence and time of maximur Includes rare forms.

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